UDC: 004.6/.8:378.147
Review article

ENHANCING EDUCATION THROUGH TAILORED IoT AND BLOCKCHAIN INTEGRATION

Avni RUSTEMI[1], Merita KASA HALILI[1], Festim HALILI[1]

[1]*Department of Informatics, University of Tetova, North Macedonia*

Abstract

The management of high-capacity data, its security, and secure transfer to various storage, whether centralized or distributed, is one of the problems that various researchers are facing on the path towards the digitalization of various services in various public and private institutions. Education is one of the spheres that is in transition to the digitization of services, where more and more attempts are being made to fully digitalize all services in schools and higher education institutions, with the sole aim of increasing quality and providing services to students at all times. The main challenges in this direction are numerous, however, among the most important are security, transparency, integrity, reliability, and privacy as characteristics that are directly related to students. By examining practical use cases and architectural models, this study proposes a conceptual model for synergistic IoT–blockchain adoption aimed at improving learning outcomes, administrative efficiency, and institutional accountability in modern education systems. The development of industry 4.0 and 5.0, in addition to requiring the inclusion of digital devices and the automation of many processes, also requires the inclusion of contemporary technologies such as IoT, blockchain, and AI, along with all their subfields, because at the moment they are the only hope that guarantees above all increased efficiency, productivity, reliability and secure data transfer. Through this paper, we will attempt to review the synergy of these technologies in education, with the aim of offering students more attractive methods of teaching, digitalization of services, flexibility in their schedules, and above all, preserving the privacy and integrity of their personal data. This research explores how tailored implementations of the Internet of Things (IoT) and blockchain technology, by indicating the AI can enhance the quality and delivery of educational services.

Keywords: blockchain technology, internet of things, artificial intelligence, digitalization, integrity.

I. Introduction

Digitalization and the use of contemporary technologies a current challenge that researchers are facing. While blockchain, through a distributed ledger, offers complete decentralization, security, and identity preservation, AI tends to improve the process of automation and autonomous decision-making. Intelligent agents are everywhere these days, including in education, and the main goal these days is to make intelligent decisions based on the analysis of big data generated by IoT devices that are physically installed in certain environments. So the main goal of IoT in this regard is, above all, the collection of information and sending it to the gateways or servers that are used, whether cloud storage or blockchain storage [1]. The integration of these technologies into current systems, especially blockchain systems including IoT and AI, is a current challenge that researchers are facing. This has led to a slowdown in the adoption of the use of these technologies in education, in higher education institutions (HEIs), schools, and various online platforms. Generation and verification of documents in digital form, authorized and secure access to learning systems, various online payments, even using their own cryptocurrencies, transparent distribution of literature and scientific achievements, transparent and automatic assessments, tracking the progress of pupils and students are just a few examples of the implementation of blockchain technology in education and higher education institutions [2]. BT, through its characteristics of decentralization, transparency, traceability, security, identity, and privacy, has managed to find application in almost all spheres of life, including recently its combination with other contemporary technologies such as AI and

IoT, and their sub-techniques. What makes BT reliable and secure is the use of smart contracts and consensus mechanisms. Each node that is part of the blockchain network must necessarily fulfill the conditions specified in the smart contract, and only when consensus is achieved between all nodes and compatibility can a given transaction be carried out [3]. The use of chatbots and various intelligent agents in learning systems is an inevitable fact of massive use in today's times, which in itself involves an implementation of contemporary artificial intelligence techniques with contemporary technologies, to provide knowledge in the fastest possible form, even offering, through machine learning, natural language processing, predictive analysis and learning techniques, to generate answers to questions that students need [4]. Using AI combination techniques, it is made to reflect an AI-augmented reality space, where students and professors are offered virtual environments for the realization of their real activities. Such a thing, in addition to making the learning process more attractive, simultaneously increases the quality, facilitates the learning process, and, among other things, promotes critical thinking, creativity, and the solution of more complex problems [5]. IoT can be used in education to collect real-time information about student performance, providing personalized support and optimal resource allocation through intelligent management and the use of AI techniques. However, the integration of IoT faces numerous challenges, especially in terms of security, data privacy, real-time data transfer, real-time storage and processing, and making more reasonable decisions based on AI techniques. The integration of IoT in educational institutions, above all provides an advanced learning environment by equipping students with advanced knowledge, to see practical realizations related to their professions, to exchange knowledge in real time with professionals, etc [6]. The structure of the paper is briefly presented in Figure 1.

Figure 1. Paper structure

II. Literature review

The practical implementation of BT, AI and IoT is facing various challenges, which has slowed down the implementation of the same, which are interrelated with the challenges of Industry 4.0, therefore the same are being attempted to be bypassed with the introduction of Industry 5.0, where the main goal is their implementation and synergy, with the aim of increasing efficiency, productivity, quality, and safety. What makes BT useful is its transparent nature, which enables the creation of a network without creating complete trust between the parties, respectively enabling communication even between parties who do not know each other at all, but everything flows in transparent form, through smart contracts that automate processes, without having intermediaries in between. The classification and access to the network through public and private types of blockchain allow all participants the flexibility of storing their data and sharing it as they wish. Everything in the network is stored in the public ledger, where each member of the network, for any change he makes, must get confirmation from all the nodes of the block, otherwise the transaction remains pending and is not executed. The combination of AI and IoT is known as The Artificial Intelligence of Things (AIoT), while the combination of BT and AI is known in some ways, depending on the implementation method, as Decentralized Artificial Intelligence (Decentralized AI) when intelligent agents operate in a decentralized blockchain space, AI-Powered Blockchain / Blockchain-Powered AI, etc.

Undoubtedly, the time of the pandemic had a negative impact on the field of education, especially in higher education institutions, where many institutions were forced to work online, and to generate online certificates, even diplomas. During this period, many institutions completely interrupted the educational process, until the relevant institutions did not give the green light for physical maintenance of the educational process, but there were also institutions that continued online, and also generated online diplomas. This increased even more the suspicion of the generation of many diplomas that are not real, or that could have been misused by different people. BT, among other things, can also be used for various online payments, using cryptocurrencies or even creating your own cryptocurrencies with which you will generate all processes and services in HEI [7]. BT, in combination with AI, big data, Internet of things, has the potential to increase the efficiency, personalization of the educational system in HEIs. In this direction, many issues undoubtedly remain challenges to be resolved, such as the need for the right infrastructure and issues related to data protection [8].

DIAR is a framework that aims to implement a blockchain system in higher education institutions for the generation and verification of diplomas and other academic documents. The generation and verification of diplomas through blockchain systems is facing various real challenges during practical implementations, however, DIAR, through the tokenization of diplomas and their storage in blockchain storage, offers an easier and faster solution for the moment towards the digitization of services in HEIs [9]. The integration of BT and AI is facing numerous knowledge gaps and challenges during practical implementations, however, their convergence undoubtedly plays an important role in improving identification methods, increasing student privacy, detecting and preventing fraud, generating and providing many services in an automatic form, creating hybrid models which above all provide secure services through data encryption and decryption through advanced cryptographic algorithms and above all providing many services in favor of facilitating the educational process for students in general [10]. BT is characterized by cryptographic algorithms, secure data transfer, traceability, and data confidentiality. AI is above all characterized by real-time monitoring and decision-making in an independent and decentralized form, the creation of strategies based on data analytics for making the best possible decisions that are interpreted through intelligent agents. The synergy between these two technologies can contribute to the automatic generation and verification of documents, the improvement of mechanisms for protecting identification and privacy, the detection of various frauds and cyber attacks, distributed artificial intelligence, and the immutability of data through the hashing process and other data protection mechanisms [11].

BT can be integrated within IoT device architectures to address many issues related to flexibility, ownership, data authentication and access, security, and scalability, among others. Blockchain can also be used as a Service for IoT for P2P connections, smart contracts, transaction management, node control, digital ledger maintenance, etc. The combination of AI and BT can produce better models for making more efficient and effective, secure, and long-term decisions for intelligent agents. The implementation of smart contracts and AI, among others, can reduce potential risks, as well as automate many processes of intelligent agents [12]. Educational institutions need to analyze large volumes of data to provide better services to students, however, the more information, the more difficult it is to identify various vulnerabilities that can be introduced by malicious individuals. Usually, this kind of concepts are distributed in various components, and key differences between Service-Oriented Architecture (SOA) and Microservices Architecture by emphasizing their structural and operational distinctions. SOA is characterized by larger, reusable services that often rely on a centralized Enterprise Service Bus (ESB) for communication and typically use a shared data store. In contrast, Microservices Architecture consists of small, independently deployable services that communicate through lightweight protocols such as REST or messaging queues,

and each service manages its own database. While SOA promotes reusability through centralized governance, microservices prioritize flexibility, autonomy, and scalability, making them more suitable for modern, cloud-native applications. Therefore, the use of collaborative edge computing, blockchain-enabled 6G communication network models, and microservices are some features of Industry 5.0, which are trying to circumvent the challenges that these contemporary technologies are facing [28]. The main disadvantages of blockchain, on the other hand, are high consumption, difficult integration into current systems, maintenance, staff training for use, and high implementation costs [13]. Figure 2 presents a summary of the synergy between IoT, AI, and BT. Through the figure, we have tried to present the synergy of these technologies resulting in practical implementations in smart Education, where we have presented its 4 main components, namely: decentralized AI, Blockchain of things, Artificial Intelligence of things, and AI-Blockchain convergence. For each, we have then presented some relevant implementations that are related to the respective combinations.

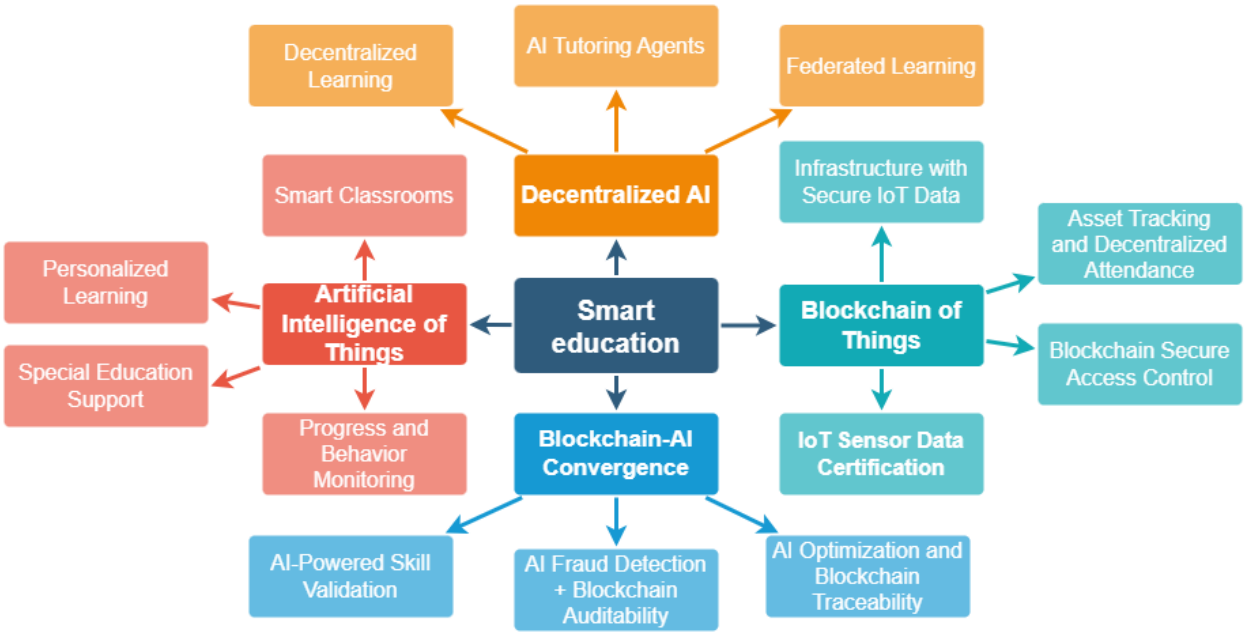

Figure 2. Integrating BT, AI, and IoT in smart education

III. Blockchain of things

BT in education, despite the fact that it is trying to be practically implemented and to enable full digitalization of services in various public and private institutions, still has many limitations and shortcomings. In many countries of the world, manipulation with various certificates, whether online or physically, is very high, therefore BT is seen as a hope for prevention, but the implementation of a blockchain system requires a lot of work and challenges, which is making it difficult to fully implement this technology, which above all offers transparency, traceability, and verification of information based on the various certificates that educational institutions possess [14]. Virtual education is a process that encourages collaboration, communication, and learning in different ways in different times and spaces compared to physical education, which has many limitations. To provide personalized and inclusive education, teachers must first understand the needs and demands of students. Therefore, there are often guidelines and training for teachers on how to behave and understand their students [15]. Students are often the target of various manipulations of their personal data. This is because there is no comprehensive platform that will protect the ownership of their personal data, and the same will have access to control their academic identity. BT, by storing data on

its network and blockchain storage, would enable a secure process of validation and verification in the education system. BT itself is immutable by nature, because the nature of its functioning is through consensus mechanisms, and as long as the information is not approved by all nodes that are part of the blockchain network, a transaction cannot be executed [16].

Several blockchain solutions have been created and practically implemented in the education sector, including systems for testing and evaluation, student record verification prototype, for traceability and tracking of student progress, verification of various documents, using various blockchain platforms such as Hyperledger Fabric, Ethereum, and in some cases combinations with AI, such as Artificial Neural Network (ANN), ERC721 standard, etc. Among others, in [17], some of the most important implementations of BT in education are mentioned: certificate management, e-learning, transfer of credits and various payments, student assessments, copyright protection, management and creation of a collaborative environment for students, and lifelong learning. The challenges of implementing BT in education are of various natures, both technical, organizational, and environmental. Scalability, standardization, integration, privacy, lack of knowledge and training, lack of norms and laws, and sustainability concerns are just some of the challenges mentioned in [17].

Education 4.0 is known for incorporating contemporary technologies such as IoT, BT, AI, and cloud computing in the field of education with the aim of digitizing services and improving quality. Despite the many challenges that Education 4.0 is facing, the same have been identified, therefore, Education 5.0 will be the era of overcoming them and the complete digitization of many services related to educational institutions [18].

IoT is one of the key technologies in the development of Education 5.0, which, through physically placed sensors and with the advancement of communication technologies, offers real-time monitoring, allowing teachers to conduct lessons in a more interactive way, involving students in concrete examples and explaining all theoretical materials to them, so that they can see their implementation in practice. Students have the opportunity to use automatic language translation devices, they have the opportunity to use Augmented Reality (AR) and Virtual Reality (VR) devices, smart headsets with sensors for mutual communication, which are connected to different types of software that are installed for the purpose of interaction between students and intelligent agents. Examples of the creation of classrooms, online meetings, and online testing are found in everyday life. Kajeet is an application that enables the monitoring of student behavior. The implementation of IoT devices has allowed professors, in addition to contributing to the increase in quality, to automate many administrative processes, significantly reducing the commitments of professors in order to spend more time on academic developments [19]. Through Figure 3, we have presented a conceptual model of synergy between IoT, BT, and AI in smart education.

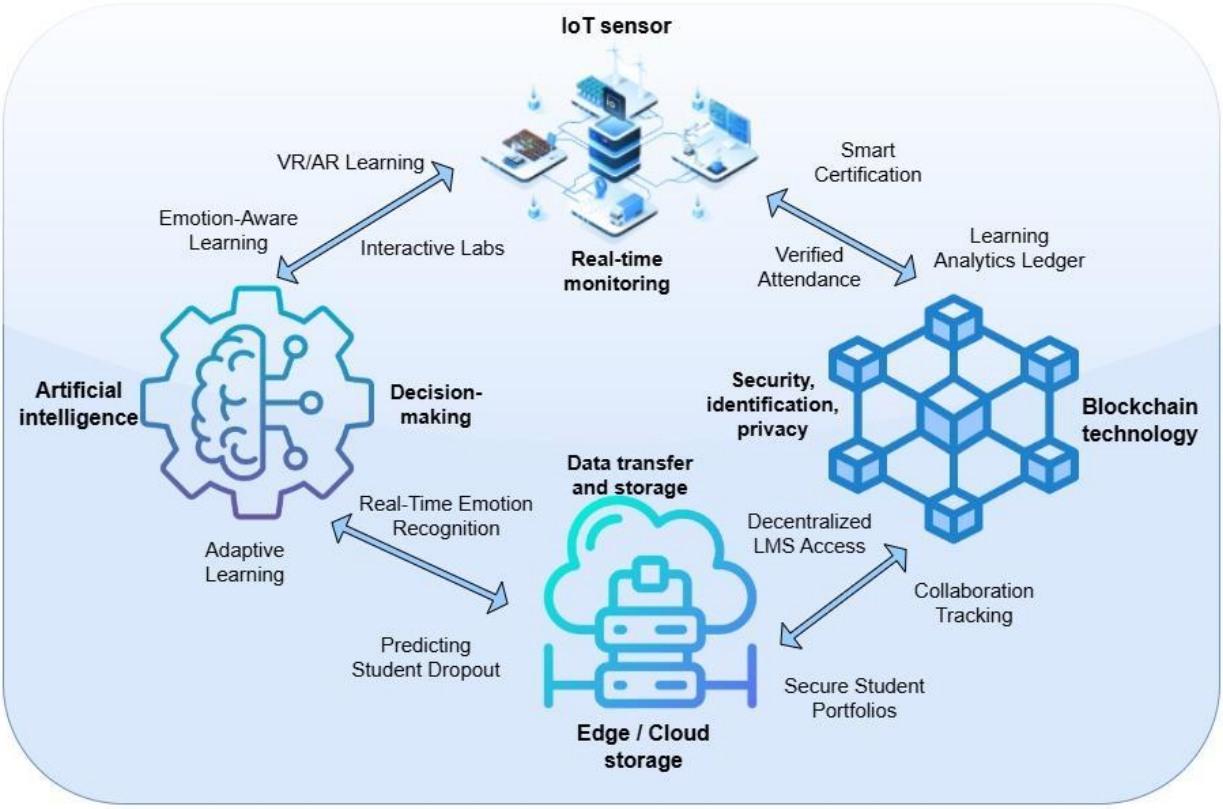

Figure 3. Smart education activities

IoT devices are those that collect information in real time, which must ideally be connected to communication networks in order to transfer data to the nearest edge storage or gateway, and finally to transfer data to the cloud or blockchain storage. BT is characterized by security, privacy, identification, and transparency. Between BT and IoT there are many activities among which we have presented smart certification, regularity, different behaviors.

Edge storage and various gateways serve for faster data transfer for security and efficiency in relation to time. The same are characterized by limited capacities, however, they have proven to be very efficient in processing data in real time, which is always in correlation with various intelligent agents.

Intelligent agents and artificial intelligence in general are revolutionizing the automation of many processes in education. There are two known modes in AI, M-mode as a mechanical mode and I-mode as an Intelligent mode, where the difference is that the M-mode concept is working within a system, whilst the I-mode paradigm is thinking about the system. In our work, we tend to pragmatically approach the Intelligent mode, meaning that our system would perceive the working process in intelligent behavior [29]. In addition to the many chatbots in this regard, intelligent agents, by analyzing data in real time, create long-term strategies and make rational decisions independently, while constantly monitoring students' emotions, behavior, collaboration, etc.

IV. Decentralized artificial intelligence

The Metaverse is an ecosystem that includes a wide range of contemporary technologies, which aim to connect the real and the digital, respectively. The metaverse cannot function without having virtual and physical environments, which it manages through Virtual Service Providers (VSP) and Payment Service Providers (PSP). The main technologies of the Metaverse are: Augmented reality (AR), Virtual Reality (VR), Extended reality (ER), artificial intelligence,

blockchain technology, IoT devices, edge and cloud computing, digital twins, avatars, and computer vision. Very important for the real monitoring of many student characteristics is the use of wearable devices, which students must place in specific places depending on the role and task of the sensor [20].

Federated learning as a powerful AI paradigm, enables, among other things, the use of Deep Neural Networks (NNs), ensuring that data remains on the local gateway, thereby overcoming the problem of data privacy and security. Knowledge Distillation (KD), a deep learning technique, is used to simulate the behavior of a smaller model, called a student, against a pre-trained model, called a tracker. The main goal is to create compact models with performance that mirrors that of larger networks. These models are important when used on devices with limited capacity, such as mobile devices or edge devices [21].

At the core of the AI revolution, whether in combination with IoT or BT, lies the concept of autonomous agents, intelligent entities that not only sense the environment in which they operate, but also analyze, learn, predict, and act independently. The integration of deep reinforcement learning (DRL) into these systems increases, among other things, their capacity and ability for more rational decision-making, making them effective even in changing environments. Self-learning, collaboration, autonomy, perception, reaction to changes, mobility, learning and adaptation, and rationality are some characteristics of intelligent agents. Machine learning algorithms enable intelligent agents to develop sophisticated models for actions in various dynamic environments, providing real-time decisions after immediate processing of data generated by IoT devices [22]. Smart education is a definition that is used as a synonym for the use of intelligent devices and information and communication technologies with the sole purpose of achieving appropriate pedagogical results. There are many prototypes, frameworks, and architectural designs that have been implemented in this direction, giving great importance to personalized/adaptive learning, collaborative learning, blended learning, and adaptive tutoring, among others [23].

Natural Language Processing (NLP) as an AI technique is very important and also one of the key factors in supporting virtual and intuitive interactions between students and virtual environments. Through NLP, virtual assistants, chatbots, and various worlds can understand and respond to students, creating more engaging and inclusive experiences. NLP can also be used to support simultaneous communication between students who speak different languages and provide real-time translations, enabling direct communication. Among other uses of NLP in the Metaverse are sentiment processing of information, audio processing, real-time question-and-answer, and information extraction [24]. By using AI algorithms to analyze data from the blockchain network, developers can create a more secure and efficient environment for data management in smart education. AI can also be used to analyze and optimize blockchain transactions, improve the efficiency and speed of transactions on the blockchain network, create decentralized virtual marketplaces, and secure systems using decentralized identity. Smart contracts as part of the blockchain enable the creation of a trusted environment for all Metaverse participants. Consensus mechanisms address the problems of Metaverse credit transactions, while the decentralized nature of data storage guarantees the security and identity of Metaverse users' digital assets. Above all, fast verification and generation through the blockchain network is also an important feature of the BT implementation. In Figure 4, we have presented the problem and the challenges which are related to the implementation of AI and BT in Metaverse, which are detailed in [24].

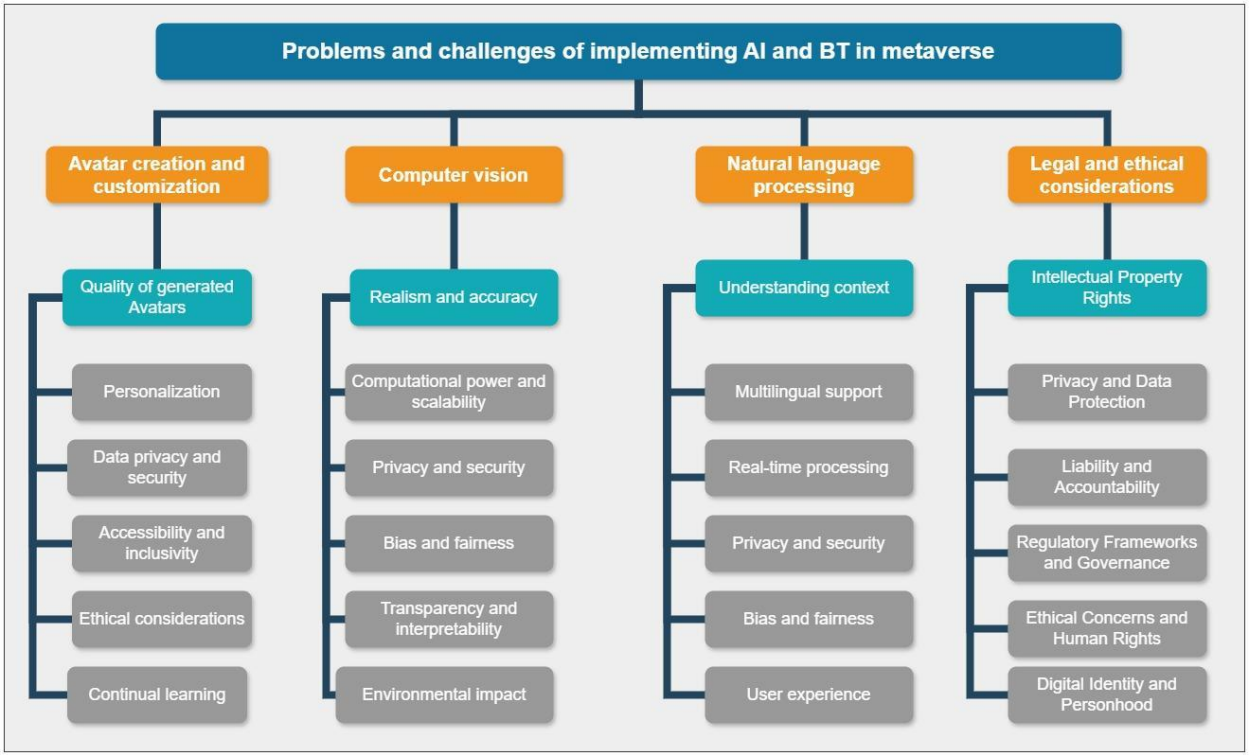

Figure 4. Challenges of implementing AI and BT in Metaverse

A. Predictive analysis through regression technique

Regression techniques can be used to predict and analyze the performance of the blockchain system at certain time intervals. Regression techniques can be used for predictive analysis, system anomaly detection, resource allocation, risk assessment, system performance optimization, market analysis, etc., smart contracts and transaction cost. The classification mainly has to do with the influence of external factors in the approach to the variables taken as a basis for the analysis [25]. Through the work and techniques of multiple regression, we present some statistics related to the verification of documents within one year in an educational institution. Initially, we assume that the institution has four (4) departments in its composition, and for each month, they generate a certain number of requests for certification of documents, which are given in more detail in Table 2. The calculation of the cost of Ethereum depends on several factors, which we have taken as examples of the data below:

Gas Price: **50 Gwei (0.00000005 ETH)**
Gas limit per verification transaction: **200,000 gas units**
Smart Contract Deployment Fee: **0.1 ETH**

Table II. One Year Document Verification Ethereum Price (Simulated Data)

A month	Average transaction value	Total transactions	Total Ether	Dep. 1	Dep.2	Dep. 3	Dep. 4
1	0.010304878	328	3.38 ETH	151	55	77	45
2	0.007398374	263	2.73 ETH	142	25	75	21
3	0.0102710027	369	3.79 ETH	145	121	58	45
4	0.0102518892	397	4.07 ETH	254	115	14	14
5	0.0102123142	471	4.81 ETH	255	114	25	77
6	0.0101934236	517	5.27 ETH	254	109	65	89
7	0.0101930502	518	5.28 ETH	266	152	44	56
8	0.0101644737	608	6.18 ETH	255	177	121	55
9	0.0101683502	594	6.04 ETH	215	200	154	25
10	0.0101808318	553	5.63 ETH	159	201	148	45
11	0.0101004016	996	10.06 ETH	455	265	254	22
12	0.0101564945	639	6.49 ETH	155	222	250	12

The following Table 3 displays the results of the regression analysis, which was calculated using the Excel application, where all details regarding the regression and how the calculations are easily performed through Excel are explained in [25,27]. Regression statistics are: Multiple Rs=1, R Square =1, Adjusted R Square=1, Standard error =3.05965E-16, Observations = 12. Degrees of Freedom (df), Sum of Squares (SS), Mean Square (MS), F-statistic (F), and Significance F are calculated based on the relevant formulas [26]. Coefficient, Standard Error, t-Statistic, P-value, Lower 95%, and Upper 95%, for departments 1,2,3,4, respectively the number of documents to be generated is calculated based on the relevant formulas, which are also explained in [25,27], and we have generated the same through Excel.

Table III. Multiple Regression Techniques for documents verification (data from Table II)

	df	***SS***	***MS***	***F***	***Significance F***
Regression	4	39.82889167	9.957222917	1.06364E+32	2.5708E-111
Balance	7	6.55303E-31	9.36147E-32		
In total	11	39.82889167			

	The coeff.	*Stan.error*	*t Stat*	*P-value*	*Low.95%*	*Upp.95%*	*Lower 95.0%*	*Upper 95.0%*
Ter.	0.1	3.32429E-16	3.00816E+14	1.1849E-99	0.1	0.1	0.1	0.1
Dep. 1	0.01	1.26123E-18	7.92875E+15	1.3407E-109	0.01	0.01	0.01	0.01
Dep. 2	0.01	2.43781E-18	4.10204E+15	1.3514E-107	0.01	0.01	0.01	0.01
Dep. 3	0.01	2.07142E-18	4.82759E+15	4.3218E-108	0.01	0.01	0.01	0.01
Dep. 4	0.01	4.41264E-18	2.26622E+15	8.6032E-106	0.01	0.01	0.01	0.01

V. Conclusion

Education is one of the most sensitive spheres in society. In order to have a bright future, and to invest in the quality of knowledge that our students acquire, it must be invested in education, digitizing the services that students use, and above all, the best, flexible, and easier knowledge to be provided. Digitalization of services is a challenge that is facing all in different spheres, such as health, agriculture, tourism, but also in education, because the use of intelligent passages requires new knowledge of the apparatus installed in the various smart applications that are used depending on the needs and duties. While IoT through the sensors installed in the environments where students operate provides real data from physically performing measurements, BT is one that guarantees security, transparency, identity, privacy, ownership, decentralization of data coming from real measurements, but also from the data that students insert through learning management systems. Intelligent agents have become an integral part of every sphere, providing service assistance across various systems, but above all by providing autonomous services that they execute based on the knowledge they collect and process through ML algorithms and other subfields of AI. In this paper, in addition to providing an overview of the synergy between these contemporary technologies in education, we also present one of the AI techniques used for prediction based on inputs generated by IoT devices or other data, which is regression. Using the regression, we have presented the data that indicates the performance based on this technique is the cost of verifying documents in any public or private institution. The challenges of implementing BT, AI and IoT are numerous, which are related to the dynamic changes that occur in the environments we live in. Despite the numerous frameworks and architectures in this direction, there are still many real challenges during practical implementations, therefore, we think that Education 5.0 will be the one that will overcome many challenges related to practical implementations.

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